The market-based dissemination of modern-energy technologies as a business model for rural entrepreneurs: Evidence from Kenya

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Abstract

This paper provides evidence on a key factor of market-based approaches to disseminate socially desirable products in developing countries: the employment and income perspectives of entrepreneurs in the related value chains. We use a staggered-implementation evaluation design to assess the impact of a large-scale intervention in Kenya that supports individuals in starting a business with improved cookstoves or small solar products. The results demonstrate how trained entrepreneurs intensify and diversify their income-generating activities, often by shifting away from subsistence farming as a main source of income. This goes along with sizeable improvements in individual and household incomes as well as perceived economic well-being in one of the two lines of business, cookstoves. Impacts do not only differ between the two technologies but also across subgroups including gender, age, education, and baseline occupation. Our findings substantiate that market-based interventions can foster modern-energy access in rural areas by supporting the establishment of local businesses, which, however, not necessarily increases incomes. At the same time, we identify several specificities of the study context that should be taken into account when considering the adoption of this approach.

Keywords: Energy access, cookstoves, impact evaluation, entrepreneurship training, business development services, entropy balancing.

JEL codes: O13, O33, H43, L26

I. Introduction

Lighting and cooking are the two most essential energy services. Large parts of the developing world, however, only have access to traditional types of these services: Eighty-three percent of the rural population in Sub-Saharan Africa, for instance, lack access to electricity and an even higher proportion lacks access to clean fuels and technologies for cooking (World Bank 2017). In order to alleviate these deprivations, international organizations and national governments have promoted the use of improved cookstoves and small-scale solar lighting solutions (Martin et al. 2011, Grieshop et al. 2011). Such activities have recently gained momentum with the creation of the global Sustainable Energy For All initiative (SE4All) that envisions universal access to modern energy by 2030. The impact evaluation literature generally substantiates the claims of these initiatives, including the social desirability of more widespread uptake, but also hints at moderate impacts on the livelihood of beneficiaries for small-scale solar lighting solutions and at heterogeneous impacts of improved cookstoves.[1]

Many of the initial dissemination models based on direct subsidies for purchasing stoves, however, were criticized by experts for low adoption rates or a lack of sustained demand (Simon et al. 2014). As a response, donor organizations experimented with market-based models. Recently, SE4All called for a stronger inclusion of private actors and market mechanisms to achieve its ambitious target (SE4All 2014). Besides the involvement of larger multinational enterprises (see D'Amelio et al. 2016), one approach is to integrate local entrepreneurs in the value chain to ensure demand-driven supply. This is thought to achieve two ends with a single effort: besides the dissemination of affordable modern-energy technologies to areas that are often cut off from related supply chains, market-based models are supposed to generate non-farm employment opportunities in areas that often struggle with unemployment and a strong dependence on agriculture.

A growing literature is dedicated to demand-side factors related to the adoption of new energy technologies (see, e.g., Malla and Timilsina 2014 or Lewis and Pattanayak 2012 for a review). Yet, the review by Rehfuess et al. (2014) likewise shows that little is known about appropriate and reliable supply chains, which are just as important for successful modern-energy technology dissemination. The authors particularly highlight the challenge to sustain income for entrepreneurs in the value chain in the long run considering seasonality issues and a relatively poor market segment. Finally, as will be discussed below, there is little evidence on the effectiveness of similar interventions aimed at increasing self-employment among rural entrepreneurs.

This paper contributes to closing this knowledge gap in the development literature with first rigorous insights into the employment and income impacts of business development support on modern-energy technologies. More broadly, we address the question whether there is leeway for governments or donors to serve markets for socially desirable products by supporting local entrepreneurs. Specifically, we study a large-scale intervention in rural Kenya related to improved cookstoves and small solar products. The program follows a market-based approach with the intention to achieve a sustainable supply of and demand for these products: prospective micro-entrepreneurs are mobilized in their local communities and trained in relevant technological and business skills. The intervention places additional emphasis on continuous business support and customer-side activities. This study evaluates the intervention as an integrated package of these activities and its effects on product sales as intermediate outcomes, and ultimately on employment and income indicators.

Our identification strategy takes advantage of the continuous start of new business trainings to compare previously trained entrepreneurs (treatment group) with new training participants (comparison group). Among new training participants, we restrict the analysis to those individuals who were later found to have taken up the business. That is, we exploit the staggered program implementation to generate quasi-experimental treatment and comparison groups in a cross-sectional setting complemented by panel information on compliance among the comparison group. Despite a careful selection of treatment and comparison sites, biases may remain that originate from a potentially non-random rollout of the intervention. To minimize this bias in our impact estimates, we account for remaining observable baseline differences between treatment and comparison groups through regression adjustments along with a covariate rebalancing approach called Entropy Balancing (Hainmueller 2012). While these covariates include proxies for motivation and entrepreneurial spirit, we acknowledge that they may not perfectly account for related unobservable confounders. The underlying survey data were collected in mid-2015 among 648 entrepreneurs of which 265 are previously trained, active entrepreneurs with on average three years of experience in the business. Among the remaining 383 training participants, those 300 individuals form the comparison group who continued in the businesses they were trained in, as identified in a follow-up survey at the end of 2016.

The empirical results show an increasing diversification and intensification of income-generating activities among active entrepreneurs in both the solar and stove business. In addition, the intervention appears to reduce the reliance on agriculture. At the same time, only cookstove entrepreneurs experience a significant increase in their individual net income and household expenditures. We thus find evidence that interventions which complement demand-side activities with market-based approaches on the supply-side can successfully deploy modern-energy technologies even in remote areas. An examination of the broader market context, however, also advises for careful case-specific scrutiny of the transferability of findings in light of the particularities of the Kenyan market and the dynamics in the energy-access technology market in general.

The paper is structured as follows: Section II provides a description of the intervention as well as background information on labor markets and energy provision in rural Kenya. Section III lays out the empirical identification strategy and describes the survey data collected. Impact estimates on a series of employment- and income-related outcomes are presented in section IV. Section V concludes.

II. The intervention and its context

A. The energy sector and labor market in Kenya

Improved cookstoves are not new to Kenya: stove research and development led to the emergence of an improved charcoal cookstove in the 1980s, the Kenyan Ceramic Jiko (KCJ), and several international organizations have been actively disseminating improved cookstoves in rural areas (Tigabu et al. 2015). People are becoming more aware of the concept and importance of clean cooking, but firewood is still the main cooking fuel for more than 80 percent of households in the country's rural areas (KNBS 2011). Overall, wood provides 70 percent of Kenya's national energy needs, thereby putting pressure on local forests that already exhibit the lowest coverage rate in the region (7.6 percent of the country's land surface according to World Bank 2015). With the increasing need to buy firewood, people are further encouraged to use energy-saving stoves. The private sector is becoming more dynamic, and some international companies also manufacture stoves locally (e.g. Burn Manufacturing or Envirofit). So far, however, only advanced charcoal stoves got traction in the market, whereas the adoption of advanced wood-burning and alternative fuel stoves face numerous challenges (see also Mortimer et al. 2017). Furthermore, the majority of actors across the cookstove and fuels value chain are artisans and micro and small enterprises (MSEs).

Electricity access is a similar challenge in the country. As of mid-2014, Kenya's electrification rate was 35 percent at the national level and only 10 percent in rural areas (MEP 2015). Even though considerable improvements in electrification rates have been achieved in the meantime, it is questionable whether households will always find the means to afford the costs associated with grid electricity. In rural areas, solar power may provide affordable, sustainable and cost-effective alternatives or at least bridging technologies to grid connections (see, for example, Lenz et al. 2017 and Grimm et al. 2017). Again benefiting from a dynamic private sector, Kenya is one of the most developed markets for solar power solutions in Sub-Sahara Africa. The use of solar lighting has increased fourfold from barely 2 percent in 2009 to 8 percent in 2013 (Lighting Africa 2016).

The labor market in Kenya displays characteristics similar to those observed in many developing countries (cf. Campbell 2013, Fields 2011, Oya and Pontara 2015). With an abundance of labor and scarcity of human capital, one observes a high degree of informality and vulnerability (e.g. lack of social protection), and a predominance of self-employment and low-productivity subsistence farming. Typically, individuals simultaneously engage in different income-generating activities ("multiple job-holding") to supplement the inadequate and unstable earnings accruing from just one activity (see also ILO 2013, Mathenge and Tschirley 2015). The reliance on agriculture as a main source of income makes many, especially poor households vulnerable to external shocks (e.g. weather) and seasonal fluctuations in demand. Youth un- and underemployment is a striking feature of the Kenyan labor market: with merely 32 percent of youths being employed in 2011, the gap between youth and adult employment rates reached 43 percentage points – one of the largest in Sub-Saharan Africa (Escudero and Mourelo 2014).

Against this background, enabling poor individuals to start non-agriculture related businesses can be an important step to diversify their sources of income. In particular, rural non-farm employment can provide a source of income to the landless poor and those who are unable to participate in agricultural activities. In addition, these entrepreneurs may create further non-farm employment opportunities for individuals within their business and along the value chain with potential positive net employment effects.

B. The intervention: Energising Development Kenya

The energy-access intervention we study, called *Energising Development Kenya*, is implemented under the umbrella of the global Energising Development (EnDev) program. EnDev's main goal is to provide poor people in developing countries with sustainable and affordable access to modern energy services through self-sustaining local markets. The Kenyan EnDev program (EnDev-K) was established in 2006, initially as an add-on to the Private Sector Development in Agriculture (PSDA) program, which aimed at value chain development within the Kenyan agricultural sector. EnDev-K was supposed to benefit from PSDA's wide presence in rural areas and the strong focus on private sector development (Berk 2016). The program is implemented by German International Cooperation (GIZ) and the Dutch non-profit development organization SNV. In 2015, GIZ covered 18 of the 47 counties in Kenya and has intervened in another 6 counties until recently, all located in the Western, Central and Lake Victoria region. SNV additionally intervenes in a total of 10 counties, of which 3 are outside the GIZ counties. At the time of the study, the SNV activities were scheduled to run until the end of 2015, those of GIZ until mid-2018.

The EnDev-K program promotes two types of stoves, the Jiko Kisasa stove and the Rocket stove. This study focusses on the Rocket stove as the main stove type in terms of produced units and supported stove producers.[2] It is a stationary firewood stove that is installed in the customers' kitchen.[3] In 2012, EnDev-K additionally launched a component to promote the use of small solar lighting products – typically one lighting point potentially complemented by a mobile charger or a radio. The choice of the specific product rests with the individual entrepreneur; the only restriction is that the stoves are required to be quality approved by Lighting Africa, a joint International Finance Corporation and World Bank initiative.[4]

The intervention involves an initial training as well as continuous business development support including marketing activities and advocacy, an integrated approach also coined Technological Innovation System (TIS) approach (Tigabu et al. 2017). EnDev-K mobilizes prospective entrepreneurs through village-level meetings organized with local representatives of the Ministry of Agriculture whose network extends deep into rural areas of the country. Participants are sensitized about improved energy technologies and the opportunity for an initial training in either cookstoves or small-scale solar business is announced. A main criterion for being eligible for the trainings is the willingness to become self-employed and invest into the new business. In the case of cookstove trainings, participants with basic handicraft skills are chosen. In addition, each participant of a Rocket stove training is required to compile a list of 20 interested households as initial customers prior to training. The initial stove training involves a two-day group workshop, followed by practical on-site installation training. For solar trainings, up-front investments are higher and participants are supposed to already possess some non-farm business. During the two- to three-day solar training, participants are taught basics in solar technology and business and marketing skills. Trainees are then connected to local solar distributors. Both stove and solar trainings are free of charge including lunch. If required, transport and accommodation costs are reimbursed. Total training costs amount to around 90 and 130 US$ per participant of solar and cookstove trainings, respectively.

In both EnDev-K components, the initial training is part of a more comprehensive set of activities to support the entrepreneurs in establishing sustainable businesses. Firstly, these include consumer-side interventions in the EnDev-K target areas such as awareness creation and consumer education. Secondly, reporting meetings are held every two to three months among entrepreneurs in one area. These meetings serve as a basis for exchange with other actors along the value chain, occasional follow-up trainings on technical or business skills and monitoring of sales figures owing to the outcome-oriented character of the program. Entrepreneurs receive 500 to 800 Kenyan Shillings (KSh, equivalent to 0.5 to 0.8 US$) travel allowances by EnDev-K to attend the reporting meetings if they have sold at least ten stoves or pico-solar systems in the previous reporting period.

According to EnDev-K, around 1,600 individuals participated in the solar trainings of which about 500 were involved in the program and regularly reported sales numbers in 2015. The number of active stove entrepreneurs is said to fluctuate between 2,500 and 3,800. Based on EnDev-K monitoring data, until June 2015 over 120,000 pico-solar lanterns have been sold by entrepreneurs cooperating with the program, and 1.9 million improved cookstoves were in use by mid-2015.

C. Related literature

Our study broadly relates to the literature on entrepreneurship interventions in developing countries, among which three strands are of particular relevance to our study:

First, studies assessing the effectiveness of interventions that train entrepreneurs in business or technical skills. Systematic review papers report rather mixed evidence on the effects of these programs (Grimm and Pfaffhausen 2015; Cho et al. 2016; Kluve et al. 2016). However, many evaluated training interventions cater to existing (small-scale) entrepreneurs, rather than aiming to support individuals to start a business in a new field. An important question in this literature is that of targeting. While several evaluations of business trainings assess the influence of targeting, the evidence in this regard is limited (Grimm and Pfaffhausen 2015).

Some recent studies suggest that training may be less effective for female business owners (e.g. de Mel et al. 2014; Berge et al. 2014; Giné and Mansuri 2017).

Second, our research relates to studies looking at more comprehensive entrepreneurship interventions, augmenting training with further business support measures. Several recent studies test whether follow-up mentoring can enhance the effectiveness of training intervention but do generally fail to find additional benefits vis-à-vis training alone (Giné and Mansuri 2017; Brooks et al. 2018; McKenzie and Puerto 2017). Many training interventions also include some form of financial assistance, in particular those that aim at business start-up (Grimm and Pfaffhausen 2015). One notable study, Brudevold-Newman et al. (2017), tests such a bundled intervention (training plus credit) for young girls in Nairobi's poorest neighborhoods. They find that initial large impacts on incomes dissipated in the second year after treatment, and relate this to savings constraints that prevent women from smoothing consumption.

Third, our research relates to studies that look at the impact of interventions to support non-farm entrepreneurship in rural areas. Recent reviews on household income-generating activities often highlight the critical role of rural non-farm income generation for poverty reduction (Davis et al. 2017). This literature suggests that women are less likely to engage in non-farm enterprises (Nagler and Naudé 2017; Rijkers and Costa 2012). However, most evaluation studies look at interventions to increase income generation from agricultural activities, often through asset or cash transfers (e.g. Bandiera et al. 2017). The evidence of successful interventions to start non-farm business is more limited. This concerns, in particular, interventions to start a business in energy-related technologies. We found a single study, Shankar et al. (2015), which tests the impact of a four-day entrepreneurial training against a four-day empowerment training on sale levels among improved cookstove entrepreneurs. The study finds that the empowerment training led to more than doubling of sales for both male and female entrepreneurs, while women outsold men by a margin of nearly three to one.

Our study hence provides additional evidence to this literature, as we look at an intervention that provides a combined training and long-term business mentoring, which aims to induce creation of non-farm enterprises in rural areas.

III. Impact assessment approach

A. Identification strategy

The aim of our empirical analysis is to estimate the causal impact of the EnDev-K intervention on sales and labor market outcomes at the individual and household level. The policy-relevant parameter is the impact on those who self-selected into the program. This is because the specific mechanism to mobilize and identify potential entrepreneurs is considered one of the main advantages of the intervention design. We thus opted for a quasi-experimental evaluation design that takes advantage of the continuous start of new business trainings: this staggered-implementation approach addresses potential bias from self-selection by sampling later cohorts of the program as the comparison group, given that these were mobilized and selected in the same fashion as earlier cohorts, the treatment group. It thus mimics a randomized phase-in evaluation design in which not the treatment itself is randomized, but rather the order in which individuals receive the treatment.

Treatment in our case refers to the entire EnDev-K intervention. This includes the mobilization and training component of the program but also covers the continuous business development services and mentoring. Participants may thus not receive full business support in case they stop attending the follow-up meetings. In fact, our data shows that around 20 percent of program participants do not continue with the intervention following the initial training stage.

The setting is thus similar to impact evaluation approaches under partial compliance (Angrist et al. 1996). Our analysis focuses on the Average Treatment Effect on the Treated (ATT) – namely the impact of the intervention on compliers, i.e. training participants who established a solar or stove business after completion of the training and continue with the further support mechanisms. We use information on actual business take-up 1.5 years after the training to identify compliers among the comparison group. This is preferred to treating compliance as a latent variable and modelling it in a complier average causal effect (CACE) framework as proposed in Angrist et al. (1996).

In the case of the staggered-implementation design, the ATT estimator replaces the unobservable post-intervention outcome Y of compliers in the early-cohort treatment group T had they not taken part in the training, $E[Y(0)|T]$, with the pre-intervention outcomes of compliers in the comparison group, $E[Y(0)|C]$ and can further be specified as follows:

$$ATT \quad = E[Y(1)|T] - E[Y(0)|C] = E[Y(1)|t = 1, D = 1] - E[Y(0)|t = 0, D = 1], \quad [1]$$

where t refers to earlier (t=1) or later (t=0) cohorts of the program and D is an indicator for compliance (i.e. business start-up and reporting following training participation). The underlying idea of this approach is hence that pre-training outcomes in the comparison group reflect the (unobservable) potential outcomes in the treatment group had they not been trained. Mobilization and selection mechanisms of the program remained constant across time and regional units. As a consequence, the main reason for why the ATT may yield biased estimates is that program roll-out may not be exogenous to potential outcomes of both groups, $cov(t, Y) \neq 0$. EnDev-K determined initial roll-out based on (i) the presence of the predecessor program PSDA working on private-sector development in the agricultural sector, (ii) input availability for stove production, (iii) prospects of and interest in commercial stove production, and (iv) firewood scarcity (Ingwe 2005). It is thus not obvious whether there has been selectivity by the program and, if so, whether it has been adopted in commercially more thriving or socio-economically more deprived areas first. In any case, potential outcomes in the underlying populations may, a priori, not be comparable, thus creating an upward or downward bias in the estimated impact.

We address this issue at two stages of our study design: first, through a detailed ex-ante selection of survey sites to minimize potential differences between earlier and later training sites (see section III.B). Second, we apply multivariate estimation methods in a selection-on-observables framework, namely Ordinary Least Squares (OLS) and Entropy Balancing. Entropy Balancing is a non-parametric statistical reweighting approach that assigns weights within the comparison group such that pre-specified balancing constraints imposed on the sample moments of the covariates are satisfied (Hainmueller 2012). We prefer Entropy Balancing to other commonly applied matching estimators, since it has been shown to more effectively reduce covariate imbalance (Frölich et al. 2017, Zhao and Percival 2015).

In our cross-sectional setup without pre-intervention data for the treatment group, the set of potentially confounding covariates has to be carefully selected. We limit the specifications to variables that can be reasonably assumed unaffected by the intervention, both on the household and county level (see section III.C). We also include proxies for motivation and entrepreneurial spirit, which are arguably critical elements of entrepreneurial success. With Entropy Balancing, we condition on the first moment of the distribution of these variables (considering that most of the employed covariates are dummy variables) and create business-specific weights, i.e. treatment and comparison units are balanced for solar and stoves separately. As suggested by Hainmueller (2012), we apply these weights from the Entropy Balancing procedure in an OLS regression setup. In analogy to including control variables in a randomized experiment, we control for all covariates used in the reweighting step (see e.g. Marcus 2013). We estimate clustered standard errors to account for correlation of outcomes across individuals with business in the same area. We cluster standard errors on the county level rather than on the intervention-site level, which provides a more conservative approach. To this end, we follow Cameron et al. (2008) by estimating wild cluster bootstrapped standard errors in the case of a limited number of clusters, again serving as a more conservative procedure, since misleadingly small standard errors and *p*-values are avoided.

Remaining time-variant and time-invariant unobservable confounders cannot be ruled out completely. Nevertheless, we argue that the ATT estimator produces reasonably unbiased estimates in this set-up given the staggered implementation of the program and the range of relevant covariates, covering e.g. entrepreneurial spirit and factors at both the individual and regional level. That is, we assume that new training participants resemble active entrepreneurs from the earlier cohorts at the time when the latter joined the program, once we account for observable characteristics.

B. Data collection

A crucial feature of the survey design was to ensure that comparison group sites, where trainings for prospective entrepreneurs were held, were similar to survey sites at which data for already active entrepreneurs were collected. This was addressed in several ways: among all scheduled trainings within the survey period, we selected those implemented in sub-counties with a low previous engagement of EnDev or other donors. This was done in order to conduct the study in a market environment that is comparable to that of the active entrepreneurs at the time of their training. In a next step, we selected existing EnDev-K intervention areas to collect data among already active entrepreneurs for the treatment sample. We determined comparable intervention sites according to the following criteria: A priori, we excluded the 14 (of in total 47) counties defined as marginalized according to criteria of the Commission on Revenue Allocation report (CRA 2012). Main further selection criteria were the 2012 Kenyan County Development Index (CDI), based on CRA 2012, and the county-level 2015 Human Development Index (UNDP 2015). Finally, we ensured that treatment sites were sufficiently distant from comparison group training areas to avoid contamination effects. For the final sample of 21 counties, Kruskal-Wallis equality-of-populations rank tests for CDI and HDI yielded p-values of 0.75 and 0.96, respectively. The comparability of the selected counties following this quantitative approach was verified qualitatively with local stakeholders regarding cultural and intervention-specific characteristics, e.g. local availability of inputs. Comparability of further county-level characteristics that were not available at the time of the site-selection are assessed as part of the empirical analysis (see section III.C). The analysis shows that the site selection was successful in producing treatment and comparison sites that are similar with respect to our regional criteria. Eventually, the survey was carried out at 35 survey sites, which also covered 19 among the 27 counties in which EnDev-K currently operates or operated until recently. The geographical distribution of these survey counties and main sampling parameters can be taken from Figure A 1 and Table A 1 in the Appendix, respectively.

Table 1: Number of completed interviews

	Interviews			**Survey Sites**	
	Solar	Stoves	Total	Solar	Stoves
Active entrepreneurs					
Compliers (Treatment)	128	137	265	9	9
New training participants					
Compliers (Comparison)	132	168	300		
Drop-outs	56	13	69	9	8
Attritors[#]	4	10	14		
Total	320	328	648	18	17

Note: [#] Among New training participants, the compliance status could not be determined for 14 individuals. Like drop-outs, these attritors are excluded from the subsequent analysis. Tests along the lines of Fitzgerald et al. (1998) show no signs of non-random attrition.

Data collection took place in collaboration with a local implementation partner. The main data used for this study were collected between June and August 2015, and thus in a period with medium economic activity, such that the sampled information can be expected to provide a good average of the year. All sampled entrepreneurs were willing to participate in the interviews, and only four interviews could not be completed. In total, the sample comprises 648 individuals (see Table 1). The survey was carried out during monitoring meetings for active entrepreneurs (compliers from previous cohorts, i.e. the treatment group in our evaluation framework) and before or during trainings for new EnDev-K entrepreneurs. In November and December 2016, a phone follow-up survey was conducted among these training participants in order to determine whether they have actually taken up their business (compliers from the trainings at the time of our main survey, i.e. the comparison group) or whether they dropped out. As can be seen in the table, 19 percent of training participants have dropped out 1.5 years after the training, with clearly stronger drop-out for the solar component. Such phone surveys among micro-entrepreneurs have been found to yield similar measurements as in-person surveys (Garlick et al. 2016).

The questionnaire administered in the 2015 survey collected detailed information on a broad spectrum of employment- and business-related topics. While questions focused on the primary income source of respondents, the survey was designed to capture all income-generating activities representing the multifaceted nature of income generation. In the design of income-related questions, several measures were taken to enhance reliability of the self-reported answers (see Appendix Table A 2). To complement the quantitative data, semi-structured qualitative interviews were conducted with a sub-sample of survey participants as well as local project stakeholders including reporting meeting coordinators, solar and stove trainers, and representatives of the agricultural ministry.[5] Inter alia, the interviews indicate that our income-related measures are likely to be subject to some degree of underreporting, which rather increases with income and which can be expected to dominate any desire to be courteous. Entrepreneurs tend not to reveal their true income for reasons of redistributive pressure, among others (see also Grimm et al. 2017, for example). This has two implications for our impact estimates: first, if we find positive impacts, these may rather represent a lower bound. Second – and in contrast to the subjective well-being indicators we employ later in the analysis – our main income-related indicators are less likely to be affected by courtesy bias.

C. Sample statistics and balancing tests

Panel A of Table 2 displays summary statistics for key socio-demographic and county-level characteristics, which serve as covariates in our estimations. The table shows several significant differences between treatment and comparison groups before rebalancing (see column (3)). We observe, in particular, that the treatment group individuals are slightly better educated than the comparison group. A higher share in the treatment group compared to the comparison group mentions a more stable income as motivation to have started the business (21.1 percent versus 7 percent). Similarly, a larger number of already treated entrepreneurs mentioned that the opportunity simply came up to get involved in the program. At the same time, we find that a similar share of interviewees in both groups have been farmers or without an income source prior to the training, for example. Most training participants without work are students or do household work. In general, training participants have diverse backgrounds: frequently observed current main income sources among cookstove entrepreneurs are farming and artisanal work such as carpentry. Solar entrepreneurs are more often engaged in trade businesses such as kiosks or street vending (not shown in the table). As county-level covariates, we make use of the Wealth Index and county-level shares of cooking with wood and electricity access determined from the latest Kenyan Demographic Health Survey (KDHS) conducted in 2014.[6]

Table 2: Descriptive statistics of treatment and comparison groups

	Treatment mean (sd) (1)	Comparison mean (sd) (2)	Difference in means (3)
Panel A: Covariates			
Female, in %	54.3	58.7	
Age category, in %			
younger than 30	19.6	29.0	***
aged 30 – 39	32.1	27.7	
aged 40 – 49	30.9	25.7	
older than 49	17.4	17.7	
Education, in %			
primary school or less	26.8	36.3	**
secondary or vocational	50.9	43.0	*
college or university	22.3	20.7	
Ever married, in %	92.0	79.7	***
Main source of income at time of training, in %			
farming	43.0	41.0	
none	10.6	12.7	
other	44.9	46.3	
Main motivations to have started the business/ participated in the training, in %			
more stable income	21.1	7.0	***
opportunity came up	37.0	29.3	*
personal interest	48.3	54.0	
Training mobilization, in %			
by external project representative	34.5	20.4	***
by family, friend, or group member	54.2	64.5	**
by village or association representative	8.7	15.7	**
Household size, mean	5.3	5.5	
	(2.3)	(2.7)	
Flooring material, in %			
earth/ mud	49.6	56.7	*
cement	45.1	40.7	
Electricity access, in %	43.2	26.7	***
County-level Wealth Index (KDHS), mean	3.0	3.1	
	(0.4)	(0.6)	
County-level share of cooking with wood (KDHS), in %	85.7	80.2	***
County-level access to electricity (KDHS), in %	13.9	17.6	**
County-level rural employment rate (KNBS), mean	53.1	53.8	
	(7.4)	(7.2)	
Panel B: Further county-level data			
Human Development Index (HDI), mean	0.5	0.5	
	(0.1)	(0.1)	
County Development Index (CDI), mean	0.6	0.6	
	(0.0)	(0.1)	
Number of observations	265	300	

Notes: Standard deviations in parentheses. Column (3) displays differences between treatment and comparison group before covariate rebalancing. *, ** and *** indicate statistical significance from two-sample mean comparison tests on a level of 10%, 5% and 1%, respectively. County-level data sources: KDHS: own computations based on Kenyan Demographic Health Survey household-level data using sampling weights (KNBS 2015); Rural employment rate: Kenyan Population and Housing Census 2009 (KNBS 2009); CDI: Commission on Revenue Allocation report (CRA 2012); HDI: 2015 Human Development Index (UNDP 2015).

Furthermore, we balance our sample on the rural employment rate taken from the 2009 Kenyan Population and Housing Census (KNBS 2009). We see similar wealth index and employment levels across the two groups, whereas levels of wood use are lower for cooking and electrification rates are higher in the comparison group counties. When differentiating between the two types of business, it becomes evident that the situation is the opposite for stove entrepreneurs, which suggests that counties of treated stove entrepreneurs are slightly more developed than those of the stove comparison group (see Table A 3 in the Appendix).

In panel B of Table 2 we assess whether the two further county characteristics used in the county selection described above, the CDI and HDI, differ on the individual level despite our efforts of ex-ante stratification. Though we do not detect any significant differences in the composite CDI and HDI values between counties of treatment and comparison sub-sample, the county data overall suggest that it cannot be ruled out that the two compared sub-samples started out in slightly different market environments. We account for this by including the four KDHS county-level variables in the covariate-balancing procedures.

IV. Empirical results

A. Profile of cookstove and solar businesses

We begin our empirical analysis with basic business characteristics of active entrepreneurs in our sample (Table 3). It becomes apparent that the solar business is a typical product retailing business, whereas the cookstove business may rather be considered product manufacturing. This different nature is, for example, reflected in the businesses structure and workforce. Solar entrepreneurs mainly perform their business as own-account workers[7] and often rely on a network of independent resellers.

Table 3: Basic characteristics of solar and cookstoves businesses

	Treatment sample mean (sd)		Difference in means
	Solar	Cookstoves	
	(1)	(2)	(3)
Business performed as, in %			
own-account worker or self-employed	74.8	84.6	*
enterprise owner	17.3	6.6	***
employee	9.4	0.0	***
member of a group or cooperative	7.9	36.8	***
Number of months individual already performs the business	24.56 (16.63)	54.04 (41.00)	***
Employees			
Number of employees, mean	0.89 (3.86)	1.72 (3.44)	***
No employees in last three months, in %	76.3	48.9	***
Weekly pay, in KSh[‡#]	977.3 (672.8)	614.7 (609.6)	**
In-kind payment to any employees, in %	15.9	3.5	**
Resale agents			
no resale agents, in %	52.0	70.1	***
number of resellers in total, mean[‡]	3.41 (7.96)	1.40 (2.79)	***
share of sales through resellers, in %[‡]	36.3 (29.0)	38.7 (30.2)	
Has separate bank account for their business, in %	47.5	24.8	***
Ever borrowed money for their business, in %	56.7	32.1	***
Number of products sold in last month[#]	19.14 (16.00)	8.90 (5.59)	***
Revenue from solar or cookstove business in an average month, in KSh			
mean[#]	23,069 (15,031)	10,632 (8,165)	***
median	20,000	8,000	
Gender of customers is female, in %	6.7	7.1	*
Mark-up over input costs, in %[†]			
mean	31.9	272.9	**
median	27.6	91.0	
Average sales ratio between lowest- and highest-sales month, in %	22.2 (16.5)	22.4 (17.0)	
Number of observations	128	137	

Notes: Column (3) displays differences between solar and cookstove entrepreneurs before covariate rebalancing. *, ** and *** indicate statistical significance from two-sample mean comparison tests on a level of 10%, 5% and 1%, respectively. [‡] Variable measured conditional on having employees/ retailers within the last three months. [#] Variable truncated at the 95th percentile within each business component to account for cases of misreporting. [†] Mark-ups are computed based on detailed data on reported sales prices of each product type sold and the reported input prices incurred.

In contrast, half of the stove entrepreneurs have had at least one employee in the previous three months and many are organized in producer groups. Employment – in particular in the cookstove business – seems to mostly involve temporary, rather low-paid jobs. Finally, solar entrepreneurs more frequently use commercial banking products and borrow money for their business (see asterisks on statistical difference between the two business lines in column (3)). This is likely due to the retail nature of the business and the related larger capital requirements, as well as to higher education (and thus financial literacy) levels of solar entrepreneurs.

Survey respondents were also asked about sales in a typical month, in terms of the number of products sold and total revenue. One observes a considerable positive skew in the distribution of products sold and revenue, meaning that most entrepreneurs report small or moderately large figures, while few entrepreneurs sell a large number of products.

Comparing the two types of enterprises, cookstove entrepreneurs sell fewer products and report lower revenues from that business, with a median of roughly 8,000 KSh per month, in contrast to 20,000 KSh for solar entrepreneurs (80 and 200 US$, respectively). Solar sales are more than double the sales of the cookstove business for each quartile; on average 19 solar devices and 9 cookstoves are sold by the entrepreneurs per month. These differences, however, need to be put in perspective with business-specific margins. The average mark-up among cookstove entrepreneurs is 273 percent, which implies that they keep more than two third of what is charged for a stove as profit. This reflects that it is a manufacturing business and labor costs of the entrepreneur are not included in unit costs, whereas the solar business is a mere retail activity. In consequence, average profit levels prove less divergent once the difference in mark-up is taken into account.

We further look into the seasonality and volatility of sales in order to gauge whether the supported businesses provide for a regular and predictable source of income. Reported demand volatility is sizable: the vast majority of entrepreneurs in both businesses report that sales in the lowest-sales month amount to 50 percent or less of the sales in the highest-sales month. Qualitative survey responses suggest that demand is decisively influenced by specific events occurring at the turn of the year: regionally relevant cash crops are coffee and tea, for which bonuses are usually paid in November or December. School fees are due in January or February and are mentioned as the single most important factor for low demand periods by entrepreneurs.

Taken together, our data clearly reflect underlying business structures of the two modern-energy technologies. The stove business is typically performed as a rather low-volume, high-margin manufacturing business, whereas the opposite appears true for the solar retailing business. Furthermore, sales in both businesses seem to be strongly dependent on macro-level factors that drive the overall rural economy, especially farming incomes.

B. Business start-up

The starting point of the impact assessment is to analyze to which extent trained entrepreneurs were able to establish their business as an income-generating activity following the training. Table 4 presents corresponding results. The table displays mean outcomes for comparison group (values are reweighted by Entropy Balancing weights) and the corresponding impact estimates. In this case, results based on unweighted OLS regressions (column 2) are similar to results based on the Entropy-Balancing weighting presented in the last column. We focus the discussion on the latter set of estimates.

The impact estimates, first, show that a large share of entrepreneurs regard the cookstove or solar business as their main source of income. Only for nine percent of the training participants the solar or cookstove business was already an income source prior to participating in the respective training. Active entrepreneurs report roughly one income source more than new training participants. Almost 40 percent of income earners in the comparison group rely on one income source only, whereas almost all treated entrepreneurs have at least two income sources. This translates into significantly more time spent on income generation overall once engaged in the business.

Table 4: Impacts on income-generating activities and working hours

	Reweighted comparison mean	Impact estimate (se)	
		OLS	Entropy-balancing weighted OLS
	(1)	(2)	(3)
Individual is in employment, in %	88.7	10.4 (1.7)***	10.9 (1.8)***
Business is among income sources, in %	9.4	85.9 (4.6)***	88.4 (5.1)***
Business is main income source, in %	4.9	65.6 (7.8)***	65.3 (8.6)***
Number of income sources, mean	1.54	0.85 (0.09)***	0.85 (0.08)***
Only one income source, in %	38.9	-34.5 (5.4)***	-31.7 (4.3)***
Contribution of main income source to personal total net income, in %‡	69.7	-18.4 (5.7)***	-17.3 (5.2)***
if solar or stoves became main income source, in %	70.1	-12.5 (5.8)**	-10.8 (4.6)*
Working hours per week…, mean‡			
in total†	39.97	10.64 (3.06)***	10.21 (3.30)**
in respective business	0.96	23.26 (3.06)***	25.5 (3.39)***
Farming activity, in %			
among income sources‡	66.2	-1.5 (4.7)	0.9 (4.4)
main income source‡	50.4	-35.6 (4.2)***	-35.2 (4.5)***
regularly sells produce on the market	76.9	-0.95 (3.7)	1.5 (4.0)

Notes: Comparison group means are reweighted based on Entropy-Balancing weights using the covariates presented in Panel A of Table 2. Coefficient estimates are obtained from an OLS regression using cluster-robust wild bootstrap standard errors (in parentheses) and including the same Entropy-Balancing weights. ‡ conditional on earning an income. † information not available for all entrepreneurs. *, ** and *** indicate that the coefficient is statistically significant different from zero on a level of 10%, 5% and 1% respectively.

This increase in total hours worked, however, is less than the amount of hours which active entrepreneurs report to spend in the respective business, suggesting that some reallocation of working hours towards the business takes place. Importantly, even though many active entrepreneurs continue their engagement in farming, the dependence on farming as a main income source declines considerably from 50 to 15 percent. This goes along with a reduced importance of the main source of income: entrepreneurs for whom the business is the main income source report that earnings from the solar or stove business represent around 60 percent of his or her total monthly net income. Among the comparison group, the main income source represents almost three quarters of their income.

Disaggregating these results by the two business types, we find a similar pattern in the shift of income-generating activities for solar and cookstove entrepreneurs (see Table A 4). The main distinction is that the shift in income-generating activities is more pronounced for cookstove entrepreneurs. This concerns in particular the diversification away from one source of income: cookstove training participants are more often reliant on a single source of income, which is often farming, from which they derive 77 percent of their total income. In addition, the role of farming as an income source clearly shifts among cookstove training participants: while the share of individuals who sell agricultural products on the market increases[8], the share for whom farming represents the main income source drops by 38 percent. This indicates that the intervention provides non-farm income opportunities to rural farmers, in particular with the cookstove component. On the other hand, cookstove entrepreneurs spend less time in their new business than solar entrepreneurs (18 hours vs. 36 hours, respectively). We relate this finding to field observations showing that solar products are often sold while concurrently performing other trade or service activities.

Taken together, the analysis provides evidence for a reallocation, diversification and intensification of income-generating activities following the start of a solar or cookstove business: the intervention establishes the respective business as an additional and important source of income, although other activities are typically not forgone. The new business often complements rather than replaces engagement in other income-generating activities. Most importantly, the intervention succeeds to reduce the dependence on agriculture among participants, although most respondents do not give up farming entirely.

C. Individual and household income

In a next step, we assess whether the adoption of the solar or cookstoves business leads to an increase in personal and household-level income across all income sources. The first panel of Table 5 provides impact estimates for the entire group of entrepreneurs in both components, which are disaggregated by business type in the bottom two panels. Income as well as expenditure data are measured unconditional on working as this most closely captures the intervention's intended effect of providing a new source of income.

The pooled estimation results indicate significant income gains for active entrepreneurs. On average, Entropy Balancing impact estimates suggest an increase of around 4,400 KSh (30 US$) or 45 percent in total monthly personal net income above the reweighted comparison group mean. In line with this, reported household expenditures are 22 percent higher in the treatment group. This is slightly less than what could be expected, given that active entrepreneurs report to contribute around 60 percent to household income. One indicative interpretation of the overall results is that households are able to increase savings and assets following business take-up.

Looking at the impacts separately for both cookstove and solar training participants, we find significant treatment effect heterogeneity. To start with, cookstove entrepreneurs report significantly lower incomes and expenditures than solar entrepreneurs before the training. In line with the observed shift in income-generating activities, income gains appear larger among cookstove entrepreneurs. In fact, the estimated impact on solar entrepreneurs is not statistically significant at the 10 percent level. Hence, the intervention appears to reduce the initial income gap between solar and stove trainees and thus to be more effective in creating an income among disadvantaged groups. In addition, as cookstove entrepreneurs devote less of their working time to the business than solar entrepreneurs (see section IV.B), the former seem to be able to generate the additional income more efficiently.

Table 5: Impacts on individual and household income

	Reweighted comparison mean	Impact estimate (se)	
		OLS	Entropy-balancing weighted OLS
	(1)	(2)	(3)
Panel A: Pooled sample			
Personal monthly net income, in KSh	9,915	3,609 (824)***	4,417 (698)***
Household…			
total monthly expenditure, in KSh	6,033	1,154 (346)***	1,314 (257)***
weekly food expenditure, in KSh	1,293	143 (79)*	170 (65)**
Panel B: Solar sample			
Personal monthly net income, in KSh	14,435	270 (1,123)	1,167 (932)
Household…			
total monthly expenditure, in KSh	7,108	589 (507)	1,346 (273)***
weekly food expenditure, in KSh	1,625	7 (121)	18 (109)
Panel C: Cookstoves sample			
Personal monthly net income, in KSh	6,211	6,006 (692)***	6,986 (606)***
Household…			
total monthly expenditure, in KSh	5,209	1,360 (564)**	1,278 (377)*
weekly food expenditure, in KSh	979	236 (137)	309 (100)**

Notes: All outcomes are measured unconditional on working. Income and expenditure data were collected by 15 intervals. Means were calculated by matching each interval to a weighted average of its bounds; both variables are truncated at the 95th percentile within each business component to account for cases of misreporting. For the income variable, this translates into 39 observations with reported income data above 58,300 KSh (solar) and 43,300 KSh (cookstoves) being omitted from the sample. Comparison group means are reweighted based on Entropy-Balancing weights. Coefficient estimates are obtained from an OLS regression using cluster-robust wild bootstrap standard errors and including the set of covariates from Table 2, once with and once without Entropy-Balancing weights. *, ** and *** indicate that the coefficient is statistically significant different from zero on a level of 10%, 5% and 1% respectively.

D. Subgroup analyses

A recurrent finding from impact evaluations of entrepreneurship programs is the substantial effect heterogeneity across different groups of participants. This concerns in particular heterogeneous impacts by gender, age and education level (Cho and Honorati 2014). In this section, we perform a split-sample analysis along these baseline characteristics and also discuss subgroup-specific results for participants whose main income source was farming prior to training.[9]

We assess heterogeneity in terms of the two key outcomes, solar or cookstove product sales and total net incomes. We thereby intend to learn more about the program's success in disseminating modern-energy technologies and in improving incomes among training participants. In Table 6 we present subgroup-specific means in outcomes and impact estimates, along with *p*-values of the interaction of the treatment indicator and the respective subgroup dummy (using the Entropy-Balancing-weighted OLS specification as applied in the main specifications).[10]

Splitting the sample across gender reveals that females in both the solar and cookstove component earn significantly less than their male counterparts before and after the intervention. Despite males selling slightly more products, income gains appear larger for females, though not statistically significant on conventional levels: the moderator analysis yields *p*-values above 0.6 once accounting for potential confounders via covariate adjustment. These findings can be explained by gender-specific differences in fundamental characteristics: male project participants tend to have a higher level of education and to be more involved with non-agricultural income generation, both of which goes along with higher pre-intervention incomes in our sample. We conjecture that the better income-generation situation among males before joining the program seems to simply leave little room for significant increases by setting a high bar for taking up further income-generating activities.

Table 6: Subgroup analyses

	Solar				Cookstoves			
	Solar product sales in last month among treated	Personal monthly net income, in KSh			Cookstove sales in last month among treated	Personal monthly net income, in KSh		
		Reweighted comparison mean	Impact estimate (se)	N		Reweighted comparison mean	Impact estimate (se)	N
By gender								
female	18.0 (15.6)	10,535	3,182 (2,408)	111	8.1 (5.6)	2,955	7,488 (1,111)***	170
male	20.6 (16.5)	17,656	256 (1,083)	114	9.8 (5.4)	11,090	5,461 (851)***	105
difference (*p*-val) ‡	*0.39*		*0.62*		*0.09**		*0.87*	
By age								
younger than 30	25.7 (17.9)	11,922	3,014 (2,812)	70	6.9 (4.2)	3,667	6,905 (4,719)	59
30 to 39	18.9 (14.6)	15,035	2,981 (2,061)	70	9.7 (6.0)	9,333	3,355 (2,774)	74
older than 39	15.7 (15.2)	17,059	-3,506 (1,894)	85	9.2 (5.7)	5,517	8,693 (1,573)***	142
difference (*p*-val) ‡								
<30 vs others	*0.03***		*0.97*		*0.03***		*0.31*	
30-39 vs others	*0.89*		*0.08**		*0.41*		*0.05**	
>39 vs others	*0.05**		*0.05**		*0.55*		*0.12*	
By education								
primary education or less	10.4 (14.6)	5,768	3,670 (2,618)	41	8.7 (5.7)	4,769	5,948 (1,004)***	123
at least secondary education	20.7 (15.9)	16,139	765 (1,291)	184	9.0 (5.8)	6,921	7,776 (1,071)***	152
difference (*p*-val) ‡	*0.01****		*0.61*		*0.76*		*0.22*	
By previous work								
non-farmer	21.7 (17.7)	17,128	544 (2,065)	135	6.9 (5.1)	5,480	7,958 (1,589)**	83
farmer	14.0 (12.1)	11,115	653 (2,243)	69	10.1 (5.8)	7,964	5,282 (1,020)***	149
difference (*p*-val) ‡	*0.01***		*0.51*		*0.00****		*0.66*	

Notes: See notes to Table 5. Simple OLS regression results are not qualitatively different from the Entropy-Balancing-weighted OLS results and therefore not shown in this table. ‡ Tests on statistical significance of two-sample mean comparison test (product sales) and the interaction term coefficient between treatment and the respective subgroup dummy using the same Entropy-Balancing-weighted OLS specification (net personal income). A statistically significant coefficient indicates that the respective subgroup is a relevant moderator for observed impacts (i.e. not necessarily regarding differences in levels).

For females, the data suggests they do not catch up strongly with male entrepreneurs, because they are more likely to consider the business their single income source and work fewer hours in their business than males. Hence, we suspect that women are more likely to perform the business as a side-activity, next to non-market work such as household chores.

Just as with gender, for all other subgroup analyses we observe lower baseline incomes among cookstove entrepreneurs vis-à-vis solar entrepreneurs. Only training participants with low education levels show similar levels of baseline income across both business lines. Selectivity again plays a crucial role: the cookstove business is more often taken up by individuals without prior income-generating activity, especially among the younger. In contrast, individuals starting the solar business are – irrespective of their age – more likely to already have experience with non-agricultural work, notably trade. This conforms to the selection criteria applied by the program.

Within each business line, the comparison group data presented in Table 6 confirms that age, education and pre-intervention income generation are strong predictors of baseline income levels. While age is a stronger predictor for income difference among prospective cookstove entrepreneurs, education and baseline occupation appear to be more relevant predictors for baseline incomes among solar training participants.

The additional subgroup analyses suggest sizable heterogeneity in terms of sales and income impacts but sample sizes may not be enough to yield statistical significance. To start with, none of the solar business subgroups experiences significant effects, whereas this is the case for most cookstove business subgroups. The two lines of business also do not yield similar impacts across subgroups. Older individuals and farmers sell more successfully in the artisanal cookstove business. Solar sales are more pronounced among younger, well-educated and non-farming individuals. But sales volumes do not necessarily correlate with income impacts given differential adjustments of individuals to the new income-generation opportunity, e.g. via the reduction or abandonment of previous activities. Among solar entrepreneurs, less educated individuals, for example, sell significantly fewer products but experience higher income increases than better-educated entrepreneurs. The better educated solar entrepreneurs instead seem to substitute previous income sources more strongly. The near-zero point estimates on the impact of taking up the solar business for both non-farmers and farmers suggest that the solar business only yield more sizable net income benefits for those few individuals who did not earn an income before.

Heterogeneity in income impacts appears strongest for those subgroups where baseline income levels also differed strongest. Despite being less successful in attracting customers with their new business, low-income individuals generally observe stronger positive impacts on income, though not strong enough to outweigh pre-training differences in incomes. Consequently post-treatment income differences between subgroups remain significant (not shown in the table).

E. Sensitivity analyses

In a first robustness check, we exclude all new training participants from the comparison group who are already active in the respective business, and for whom the business is thus not new. This effectively only concerns 36 of the 300 individuals in the comparison group. The change in our impact estimates are marginal and insignificant for all variables. Furthermore, we test whether our results are sensitive towards the inclusion of outliers. As could be expected, changing the censoring level from the 95th to the 99th percentile strongly increases average outcomes in both treatment and comparison groups but not the direction of the treatment effect.

F. Subjective economic well-being and perceived quality of work

In a final step, a number of subjective indicators of perceived economic well-being and quality of the current employment situation are assessed to put the income impact estimates into perspective. To judge the economic well-being of entrepreneurs, respondents were asked how they perceive their current and previous economic situation, choosing from six categories ranging from very good to very bad. Since these subjective questions could be prone to courtesy bias, we attempted to account for fundamental differences between interviewees in what is perceived as good or bad by asking survey participants to judge the situation of two fictional persons based on a brief profile. Adjusting the answers by these calibration questions does not alter the overall results.

Results are reported in Table 7 for the pooled sample of cookstove and solar entrepreneurs. Overall, the analysis of subjective indicators supports the claim that the intervention improves the economic well-being of its participants. Moreover, the intervention appears to significantly improve their perceived employment quality. More than two-thirds of active entrepreneurs are satisfied with working conditions in both the cookstove and the solar business. It appears that the improvement in the perceived economic well-being mainly results from an increase in the perceived economic stability. We take this as support for the observed improved economic resilience at the individual level through a diversification of income-generating activities. At the same time, no impact on job security is found, which may be related to the strong seasonality in demand and sales discussed in section IV.A.

The impacts on perceived economic well-being and quality of work are similar across cookstove and solar entrepreneurs (not reported in the table). In line with differential impacts on personal and household-level reported incomes, cookstove entrepreneurs perceive a larger increase in economic stability. This lends further support to the general impression that the intervention affects the cookstove entrepreneurs more strongly than solar entrepreneurs.

Table 7: Impacts on perception of economic well-being and quality of work

	Reweighted comparison mean	Impact estimate coefficient (se)
Economic Well-Being, in %		
Perceived economic situation two years ago		
rather good, good or very good	49.5	2.0 (5.0)
bad or very bad	30.1	-2.8 (4.2)
Perceived current economic situation		
rather good, good or very good	78.0	13.3 (4.5)**
bad or very bad	7.1	-5.2 (2.8)
Perceived current economic situation better than two years ago	61.6	8.8 (6.8)
Only entrepreneurs not in business two years ago	62.8	12.8 (5.7)*
Household regularly has difficulties making ends meet	60.3	-17.7 (3.1)***
Quality of Work, in %		
I am satisfied with working conditions overall.	59.4	16.8 (4.1)***
The safety and health conditions are bad.	20.5	-7.2 (4.1)
I am afraid of losing my job / business in the next 12 months.	20.4	-1.4 (3.1)
I am well paid for the work I do.	48.3	15.6 (7.3)*
My work allows me to have a stable economic situation.	43.0	25.8 (5.6)***

Notes: All values refer to the share of respondents who agree to the specific statement. Agree refers to the statements "agree" or "strongly agree" on a six-point Likert scale. Quality of work indicators conditional on working. Comparison group means are reweighted based on Entropy-Balancing weights. Coefficient estimates are obtained from an OLS regression using cluster-robust wild bootstrap standard errors and including the same Entropy-Balancing weights. *, ** and *** indicate that the coefficient is statistically significant different from zero on a level of 10%, 5% and 1%, respectively.

V. Discussion and conclusions

Our empirical analysis suggests that the intervention had a distinctive impact on the income generation of supported entrepreneurs in the medium term: many shift their main income-generating activity towards the business and derive a significant share of their individual and household-level income from it. Other income-generating activities are not necessarily forgone – most entrepreneurs adopt the business as an additional rather than an alternative income source, in particular as relates to farming. This diversification and intensification of income-generating activities translates into net total income increases only for cookstove entrepreneurs in our sample. Our main impact estimate suggests that they more than double their individual incomes by almost 7,000 KSh. Their reported monthly total household expenditure increases by 1,280 KSh (25 percent) above the comparison mean. This impact goes in hand with a significant improvement of subjective economic well-being and perceived quality of work. Among solar entrepreneurs, the new business mostly seems to stabilize existing incomes without significant impacts on income or expenditure levels. This impact heterogeneity across the two business training can be partly related to pre-intervention income differences across participants between components. Even though a detailed analysis of drop-out behavior is beyond the scope of this article, it seems likely that the limited prospects of income gains for solar entrepreneurs are a main reason for higher drop-out rates in this line of business.

Our study adds important insights to the debate of an adequate targeting of entrepreneurship programs: The program successfully improves incomes among female training participants, even though the initial training intervention dates back three years on average. This is in contrast to previous evaluations of entrepreneurship trainings (e.g. de Mel et al. 2014; Brudevold-Newman et al. 2017). Generally, the subgroup analyses suggest that impact heterogeneity exists across gender, age, education and previous income-generating activities. The two business trainings attract distinct subgroups of the rural population with varying degrees of success in taking up the business and achieving net income gains. We suspect that this is related to the specific program design: applicants have to proof their motivation by proving that they can raise sufficient initial capital or customers to start a viable business after the training. Such "dynamic" selection mechanism may be more adequate than a preset targeting of eligibility groups (e.g. by gender or education level).

These results also imply that it may be the demand-driven mobilization and participant selection that allows the program to achieve two ends with a single effort: to generate non-farm income opportunities for disadvantaged groups and to disseminate modern-energy technologies in rural areas on a larger scale through higher-skilled individuals. From that perspective, a more specific targeting of training participants seems counterproductive for at least one of these two objectives – a better targeting to further reduce drop-out rates is also less critical, since training costs are relatively low in our context.

A full social cost-benefit analysis of the program would also need to take into account potential positive effects along the value chain and negative effects on competitors (e.g. producers of traditional stoves) or entrepreneurs in competing value chains (e.g. kerosene vendors). At least for the cookstove intervention, such an analysis would likely yield a positive verdict since the substitution effects can be considered as intended consequences of a transition towards sustainable energy consumption in rural areas.

While the present study can thus be said to provide proof of concept of this entrepreneurship intervention component, there are important hazards that affect the transferability of findings across time and to other locations, notably context dependence.[11] Kenya is arguably the most developed market for entry-level energy technologies in Sub-Saharan Africa. The non-financial constraints experienced by energy entrepreneurs therefore tend to be even more pronounced in other countries on the continent with similar energy access challenges. As highlighted by Haselip et al. (2015), these barriers include, inter alia, weak entrepreneurial cultures, persistent shortcomings in business skills capacity and widespread demand-side barriers. As a consequence, there are many examples of both non-profit and for-profit endeavors that failed in disseminating cookstoves or solar products among energy-poor customers (cf. Bensch et al. 2018; Sesan et al. 2013; Khandelwal et al. 2017).

Results are furthermore likely to depend on the temporal context given the strongly dynamic market environment. In fact, there are a number of critical dynamics in the energy-access market in Kenya that may limit the sustainability of impacts. First, advanced energy technologies are becoming increasingly available in rural areas. Different from most other developing countries on the African continent, grid extension has soared in Kenya in the past years and the government recently announced to achieve universal access to electricity by 2020, which at least creates expectations among the population and thus a disincentive to invest in off-grid electricity. Second, pay-as-you-go systems are becoming a commercial opportunity as they offer providers with a tool to technologically enforce payments for the use of the systems. This implies a reduced need for decentralized own-account entrepreneurial models as followed by the EnDev approach and likely goes along with a consolidation within this rather fragmented value chain (Cogan and Collings 2016). Finally, signs of market saturation are observed in some intervention areas due to the localized nature of many of the entrepreneurs' businesses.

To conclude, our findings suggest that interventions to support prospective entrepreneurs in setting up small-scale businesses on energy-access technologies may be effective in ensuring sustainable supply of these products. At least the cookstove technology appears to provide a pro-poor business opportunity in rural Kenya, also thanks to the relatively developed markets and complementary demand-side interventions, whereas solar entrepreneurs mostly seem to benefit from more stable income streams. However, the dynamic market context bears particular sustainability concerns for the solar component. To achieve wider uptake of improved cookstoves, and thus to capture the social benefits of cleaner cooking, additional effort is likely required in many countries, e.g. via smart user subsidies and targeted R&D support (Mobarak et al. 2012; Bensch and Peters 2017; Shan et al 2017).

These findings are likely relevant also for similar market-based approaches in health- or environment-related technologies that require basic technical skills such as water filters. Future research should therefore seek to assess the transferability of findings to these technologies. For the energy access market under scrutiny in this article, research on the dynamics sketched above and their effects on the market would be valuable. Likewise, more can be learnt about the potentials and effects of similar market-based approaches if interactions along the value chain would be mapped more extensively.

[1] With regards to small-scale solar lighting solutions, most studies observe positive impacts on intermediate outcomes (e.g. on expenditures and kids' study hours) but mixed evidence for ultimate impacts such as education (Grimm et al. 2017, Rom et al. 2017, Kudo et al. 2018, Furukawa 2014). Similarly, the evidence on improved cookstoves is generally positive but points to heterogeneity with respect to available ICS types (cf. Adrianzén 2013; Bensch and Peters 2013, 2015, Bensch et al. 2015, Beyene et al. 2015, Brooks et al. 2016, Rosa et al. 2014, Hanna et al. 2016, Usmani et al. 2017). For health effects, Pope et al.'s (2017) systematic review finds that smoke concentrations decrease but still exceed WHO standards by far for most ICS types.

[2] In the three years preceding the evaluation, semi-annual shares of Rocket stove sales in total sales of the two supported stove types were always at around two-thirds and the share of Rocket stove entrepreneurs among all supported entrepreneurs at 80 to 90 percent. It can, however, not be inferred that Rocket stoves sell better than Jiko Kisasa stoves. In areas where both stove types are sold Jiko Kisasas are actually in higher demand because they tend to be cheaper. Implementation is majorly guided by the local availability of relevant raw materials. In contrast to Rocket stoves, Jiko Kisasa stoves furthermore lend themselves to less labor-intensive mass production, which is why we see more entrepreneurs involved in the fabrication of Rocket stoves.

[3] For further technical details on improved cookstoves, see for example, Kshirsagar and Kalamkar (2014).

[4] At the time of the survey, the most demanded brands were d.light, SunKing and Sundial.

[5] See RWI (2016) for further details on the study implementation.

[6] The DHS wealth index is generated via a principal components analysis based on household asset data collected as part of DHS. It has been demonstrated to be consistent with expenditure and income measures (Rutstein and Johnson, 2004). For Kenya-specific details, see KNBS et al. (2015, p. 17ff).

[7] According to the International Classification by Status in Employment, "own-account workers" hold self-employment jobs (i.e. jobs in which the remuneration is directly dependent upon the profits derived from the goods and services produced) and do not engage any employees on a continuous basis (cf. Campbell 2013).

[8] This finding – counter-intuitive at first – is in line with recent research showing that participation in off-farm self-employment is linked to increased spending on agricultural inputs and incomes (Dedehouanou et al. 2018).

[9] In contrast to the gender-specific impact analysis, the other subgroup analyses were not specified prior to conducting the impact analysis. They should be regarded as indicative evidence. One could additionally adjust tests statistics to account for multiple hypothesis testing. We refrain from this exercise given that most interaction effect coefficients are not significant.

[10] In the case of product sales, p-values are derived from two-sample mean comparison tests between respective subgroups in the treatment sample only. Therefore, these tests also have lower power than other tests conducted in this paper.

[11] The external validity literature highlights further threats to generalizability (see Banerjee et al. 2016 and Peters et al. 2016). However, many of these issues are related to the particularities of randomized controlled trials (RCTs), which are circumvented through our observational study approach on a large-scale program, including equilibrium or Hawthorne effects.

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Appendix

Table A 1: Main sampling parameters

	Treatment sample (active entrepreneurs)	Comparison sample (new training participants)
main program participation condition	active since 2014 or earlier	attending training during the time of data collection
survey region	existing GIZ intervention counties comparable to new training sites in terms of socio-economic and cultural factors	GIZ or SNV pull-in counties
survey site and timing	at monitoring meeting held during data collection period	at start of training conducted during data collection period
sampling frame	lists of active entrepreneurs in zones where monitoring meetings are held	participant lists of upcoming GIZ or SNV trainings
timing of sampling	ad hoc random sampling at monitoring meetings*	ad hoc random sampling based on training participant lists
envisaged number of interviews per site	up to 20	20 (solar) 25 (stoves)

Notes: Pull-in counties refer to counties, where the GIZ activities are about to start or have started only recently. * It was originally planned to conduct random sampling before monitoring meetings based on lists of active entrepreneurs. However, either the number of participants turned out to be too few for sampling or the lists were not comprehensive so that it was opted for ad hoc sampling during the meetings.

Table A 2: Measures to increase the reliability of self-reported income figures

Measure	Description
Showcards	• The use of specific showcards for income questions, which only ask for intervals and allow respondents to give their reply in a coded way. Referring to the letter displayed on the showcard allowed the interviewee not to directly disclose his or her income to the interviewer.
Sensitization through key stakeholders	• Strong sensitization of coordinators and mobilizers of the different groups and meetings as well as officials, since they were the key people to gain trust of the individual entrepreneurs.
Training of enumerators	• Specific explanations given during the interviews to reassure interviewees that the information would be treated fully confidentially in order to make them feel at ease.
Corroboration of information	• Corroboration of income information through sales information provided by the interviewees. • Use of the EnDev monitoring data to further corroborate the answers given by entrepreneurs already cooperating with the program.
Proxy variables	• Use of a wide range of proxies for income such as expenditures and assets/ wealth, both for business and private.

Table A 3: Descriptive statistics of treatment and comparison groups, by business

	Solar			Cookstoves		
	Treatment	Comparison	Diff. in means	Treatment	Comparison	Diff. in means
	mean (sd)	mean (sd)		mean (sd)	mean (sd)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Covariates						
Female, in %	53.9	46.2		54.7	68.5	**
Age category, in %						
younger than 30	22.7	34.8	**	16.8	24.4	
aged 30 - 39	38.3	27.3	*	26.3	28.0	
aged 40 - 49	25.0	22.0		36.5	28.6	
older than 49	14.1	15.9		20.4	19.0	
Education, in %						
primary school or less	14.8	18.2		38.0	50.6	**
secondary or vocational	47.7	43.2		54.0	42.9	*
college or university	37.5	38.6		8.0	6.5	
Ever married, in %	89.0	75.0	***	94.9	83.3	***
Main source of income at time of training, in %						
farming	32.0	27.3		53.3	51.8	
none	9.4	7.6		11.7	16.7	
other	56.3	65.2		34.3	31.5	
Main motivations to have started business/ participated in training, in %						
more stable income	20.3	9.1	**	21.9	5.4	***
opportunity came up	42.2	28.8	**	32.1	29.8	
personal interest	49.2	54.5		47.4	553.6	
Training mobilization, in %						
by external project representative	32.8	21.2	**	36.0	19.8	***
by family, friend, or group member	60.9	70.5		47.8	59.9	**
by village or association representative	3.1	6.1		14.0	23.4	**
Household size, mean	5.3	5.1		5.3	5.8	*
	(2.5)	(2.6)		(2.2)	(2.7)	
Flooring material, in %						
earth/ mud	35.4	35.6		62.8	73.2	*
cement	55.9	61.4		35.0	24.4	**
Electricity access, in %	55.9	42.4	**	31.4	14.3	***
County-level Wealth Index (KDHS), mean	3.0	3.2	***	3.0	2.9	**
	(0.4)	(0.8)		(0.4)	(0.3)	
County-level share of cooking with wood (KDHS), in %	85.9	69.1	***	85.6	88.9	***
County-level access to electricity (KDHS), in %	11.1	26.0	***	16.4	11.0	***
County-level rural employment rate (KNBS), mean	51.0	51.7		55.1	55.5	
	(8.3)	(8.2)		(5.8)	(5.7)	

Table continues next page

Table continued

Panel B: Further county-level data						
Human Development Index (HDI), mean	0.5 (0.1)	0.5 (0.1)	*	0.5 (0.0)	0.5 (0.1)	***
County Development Index (CDI), mean	0.6 (0.0)	0.6 (0.1)	**	0.6 (0.0)	0.5 (0.0)	***
Number of observations	128	132		137	168	

Notes: See note to Table 2.

Table A 4: Impacts on income-generating activities and working hours, by business type

	Solar			Cookstoves		
		Impact estimate (se)			Impact estimate (se)	
	Comparison mean	**OLS**	**Entropy-balancing weighted OLS**	**Comparison mean**	**OLS**	**Entropy-balancing weighted OLS**
	(1)	(2)	(3)	(4)	(5)	(6)
Individual is in employment, in %	89.6	6.7 (1.2)***	9.6 (2.4)***	88.4	11.2 (2.3)***	11.6 (1.6)***
Business is among income sources, in %	10.0	86.3 (5.6)***	87.7 (5.8)***	9.5	87.5 (6.8)***	88.3 (6.1)***
Business is main income source, in %	5.5	67.9 (11.2)***	65.6 (11.8)***	3.1	68.8 (9.3)***	66.2 (9.2)***
Number of income sources, mean	1.69	0.79 (0.11)***	0.80 (0.12)***	1.41	0.96 (0.09)***	0.89 (0.08)***
Only one income source, in %	33.3	-26.0 (8.4)**	-24.7 (7.34)**	43.7	-44.8 (3.6)***	-37.8 (3.0)***
Contribution of main income source to personal total net income, in %‡	61.1	9.8 (6.3)	-9.9 (5.5)	77.0	-26.3 (5.5)***	-23.5 (4.0)***
if main income source is solar or stoves, in %	63.7	-3.6 (7.9)	-4.0 (6.5)	75.8	-21.1 (4.8)***	-17.0 (3.0)***
Working hours per week…, mean‡						
in total†	42.87	10.01 (5.71)	12.76 (5.07)	36.95	7.39 (5.78)	7.78 (6.53)
in respective business	0.22	34.08 (3.95)***	35.62 (3.83)***	0.73	15.13 (2.30)***	17.30 (2.18)***
Farming activity, in %						
among income sources‡	52.1	4.5 (6.1)	-0.2 (5.1)	78.6	3.1 (3.9)	2.4 (4.7)
main income source‡	38.1	-30.3 (5.6)***	-31.8 (6.2)**	61.8	46.1 (6.3)***	-38.4 (7.6)***
regularly sells produce on the market	76.0	-9.0 (3.1)**	-8.0 (3.8)	77.2	9.9 (2.6)***	11.0 (4.1)*

Notes: See notes to Table 4.

Figure A 1: Location of survey sites